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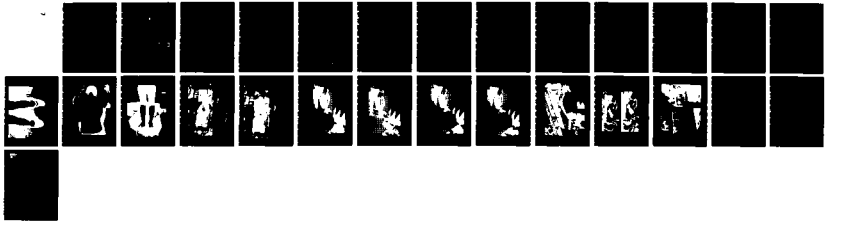

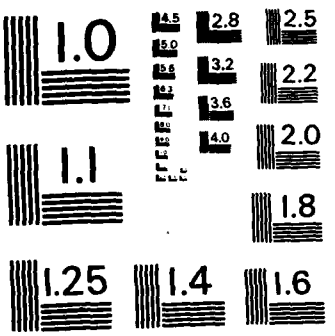

REPORT NO. NADC-84009-60

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PHYSIOLOGICAL ACCEPTABILITY TESTS OF THE MODIFIED SJU-5/A EJECTION SEAT FOR THE F-18 AIRCRAFT

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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

The program was conducted to demonstrate physiological acceptability of the Martin-Baker SJU-5/A (modified) Escape System planned for installation in the Navy's F-18 aircraft. Twenty ejection tests were run on the Naval Air Development Center Ejection Tower Facility using both anthropomorphic dummies and human volunteer test subjects. As a result of this program the seat was found to be physiologically acceptable.

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INTRODUCTION

Emergency ejection experiences from the F-18 aircraft have indicated that there are physiological related problems with the SJU-5A ejection seat which warrant design modifications to specific seat components. These modifications were made and the purpose of this test program was to assess whether they improved the physiological acceptability of the SJU-5/A ejection seat.

The following modifications were made to the seat and rudder pedals.

a) A stiffened backwedge with a 15.5° back angle

b) A 2.0 inch head pad

c) A dynafoam seat pan cushion

d) Increased spring stiffness of the toe guides

This report describes the testing performed, problems encountered, and recommendations for corrective action. A production-configured SJU-5/A ejection seat with unnecessary components removed, and a simulated frangible F-18 crew station were mounted on the NAVAIRDEVCEN ejection tower facility for this program. The initial phase included a series of tests using anthropomorphic dummies as seat occupants to verify system safety and to calibrate the propulsion system. Calibration included development and verification of catapult/carriage configurations to simulate ejection seat acceleration profiles expected during actual Fleet usage. The second phase of the program consisted of tests with four human volunteer subjects as seat occupants. Each human subject began the test series with an indoctrination test attaining a peak acceleration of 7 G. Subsequent tests were conducted with increasing accelerations until the maximum operationally expected accelerations of 12 to 14 G were reached by each subject. Incrementally increasing the acceleration is a standard procedure to insure subject safety and to permit detection of a threshold of injury.

SUMMARY OF RESULTS

The Martin-Baker SJU-5/A escape system as modified for this program produced considerably less head rotation and foot/cockpit interference than the originally configured article previously tested on the NAVAIRDEVCEN ejection tower. Reduced head rotation was evident with the new backwedge/headrest geometry. However, the new backwedge still has a deficiency which must be corrected prior to fleet incorporation. Its height and contour is such that a subject experienced a severe pain and bruising during an 11 G build-up test. The cause of the contusion was contact of his scapula with the top of the backwedge. To complete the test program an ensolite pad was shaped and placed on top of the backwedge to prevent scapula impingement. A redesign of the top of the backwedge or the cushion covering it must be improved by the Navy before the system can be considered to be physiologically acceptable. The dynafoam seat kit cushion was found to be acceptable.

CONCLUSIONS

The physiological acceptance of the SJU-5/A escape system is contingent upon Navy approval of a new backwedge or backwedge cushioning which will eliminate scapula impingement. The stiffened backwedge at a 15.5° back angle, the 2-inch head pad, the dynafoam seat pan cushion and stiffer toe guides were found to be acceptable.

RECOMMENDATIONS

A higher backwedge or increased padding on top of the present backwedge cushion should be incorporated to prevent scapula impingement. The new design should be submitted to NAVAIRDEVCEN for approval. If the correction replicates the final tested configuration no additional tower testing will be required to grant physiological acceptance.

TEST SETUP DESCRIPTION

All tests described herein were conducted on the NAVAIRDEVCEN ejection seat tower facility. The ejection seat tower is a 150-ft structure inclined and supported at an angle of 20 degrees, 50 minutes from the vertical. It is capable of accepting any current ejection seat and has been used for a variety of studies related to egress systems. Being man-rated, it is an important tool in determining the physiological acceptability of escape system acceleration forces using human volunteer subjects.

The following describes the major components used in conducting the tests described in this report:

EJECTION SEAT

1. SJU-5/A ejection seat MBEU 65101, issue A, serial No. HTT-0001. All unnecessary components were removed from the seat to minimize total ejected weight (TEW) on the tower. Components retained on the seat were as follows:

    a. Assembly of main beams and mechanism MBEU 69861-2, issue A, serial No. 0001.

    b. Harness reel MBEU 65243, issue D, serial No. 0035.

    c. S. R. actuator MBEU 65283, issue E, serial No. 0004.

    d. Assembly of seat bucket and locking mechanisms MBEU 65620-1, issue A, serial No. 0001.

    e. Parachute container MBEU 10540PA2, issue A, serial No. 0001.

    f. Head pad MBEU 69726, issue A.

    g. Back support MBEU 0/78 66940-1, serial No. 0024, issue B.

    h. Back pad MBEU 1/79 66943-1, issue A.

    i. Leg restraint snubber mechanisms MBEU 66607.155A (LH) MBEU 6608.155A 16443. (RH).

    NOTE: Components removed from the seat were not considered pertinent to the test results.

2. Survival kit/cushion

    a. SKU-3/A Rigid Seat Survival Kit (RSSK), East-West Industries, Inc. (EWI), P/N 253J100-1, HTT-0050.

    b. Dynafoam Cushion (No P/N – No Identification).

3. Torso Harnesses

The torso harnesses used were standard or cut-away MA-2's.

4. Communications System(s)

a. Helmet – APH-6

b. Oxygen mask – MBU-14/P

5. Aircrew Station Mockup

a. Instrument Panel – MDC SKRLM033183-2001 (only for the 12-14 G tests).

b. Toe guides – MDC SKRLM111982-2001 (only for the 12-14 G tests) or 74T043238-1002/2007 (for all build-up tests)

TEST SUBJECTS

A Hybrid II 50th percentile adult male anthropomorphic test dummy was used as the seat occupant for safety checkout and calibration tests. Four volunteer adult males were then used to determine the physiological acceptability of the modified seat. Anthropomorphic measurements for these test subjects are listed in table I which includes adjusted seat heights and rudder pedal positions for each subject.

MEDICAL SUPPORT

For any test program conducted by the Navy which involves the exposure of human subjects, stringent regulations must be followed to insure maximum safety for the subject. For this program a medical support team was on site before, during and after each human subject test. The team was headed by a Medical Officer and included as a minimum, a senior corpsman and two rated corpsmen. In addition, a ready ambulance was on site for each test, plus a portable defibrillator and other emergency medical supplies. Each subject was monitored for EKG response before, during and after each test, and had direct communications with the Medical Officer and the test directors for an immediate report of physical condition.

TABLE I
HUMAN TEST SUBJECT DATA

Subject	Stature CM–Percentile	Buttock-Knee Length CM–Percentile	Knee Height Sitting CM–Percentile	Shoulder Height Sitting CM–Percentile	Seat Height Up Adjustment In.	Rudder Pedal Position Forward In.
1	174.4–38	54.1– 2	50.8– 3	63.4–67	1-1/2	6
2	175.9–44	61.0–53	52.6–14	62.7–58	2	8
3	180.2–68	61.5–57	54.5–39	65.9–91	3/4	9
4	180.4–69	61.1–54	54.8–43	64.9–84	1-3/4	10

Percentiles are based on NATC Report No. SY-121R-81, the 1981 Naval and Marine Corps Aviation Anthropomorphic Survey.

INSTRUMENTATION DATA TECHNIQUES

The electronic instrumentation data recorded for this program included catapult pressure, vertical catapult acceleration, vertical seat acceleration and seat displacement. In addition, during dummy tests, triaxial accelerations were recorded in the dummy head, thorax, and pelvis. All instrumentation was calibrated in accordance with standard NAVAIRDEVCEN procedures. Analog signals were recorded on a direct writing oscillograph for "quick-look" analysis and parallel recorded on a magnetic tape to permit a more detailed data analysis subsequently to the test. All of the original electronic instrumentation records and tapes are available at NAVAIRDEVCEN.

PHOTOGRAPHIC DATA TECHNIQUES

Table II lists the photographic camera's and their placement for the series of tests. Their purpose was to record subject body motion during each test for later analysis.

All films and photos are available at NAVAIRDEVCEN.

TABLE II
CAMERA INFORMATION

Camera No.	Manufacturer	Film Speed	Lens Size	Camera Location and Coverage
1	Photosonics	1000	13 mm	Right side of tower First foot of seat travel
2	Photosonics	1000	25 mm	Right side of tower Last foot of seat travel before separation
3	Photosonics	1000	25 mm	Front of tower Entire ejection stroke
4	Miliken	400	40 mm	Front right side of tower tracking
5	Miliken	400	15 mm	Right side of tower Entire ejection stroke
6	Miliken	400	25 mm	Above the seat Entire ejection stroke
7	Miliken	400	40 mm	Close up of left foot travel off the rudder pedal and past the instrument panel mock-up (only for 12-14 G human tests)
8	Nikon	Single Frame	50 mm	Right side of seat At 6 inches of travel
9	Nikon	Single Frame	50 mm	Right side of seat At catapult separation

TEST RESULTS

Table III is a summary of test conditions and important performance measurements required by Reference 1.

The new backwedge and head rest pad geometries were verified before the tests by the use of a template supplied by McDonnell Douglas Corporation. This template can be seen on the seat in figures 4 and 5. The subjects experienced almost no head rotation with the new seat geometry during this test as seen in figures 6 through 9 showing each subject at the end of the catapult stroke.

The backwedge as presented at the onset of this test series is unacceptable because it allows scapula impingement. Figure 10 shows the location of the scapula of subject No. 3 with respect to the backwedge. This same subject is shown in figure 11 just prior to ejection initiation and at 6 inches of seat travel. His upper torso can be seen above the backwedge even as his body compresses during the ejection stroke. In order to complete the test program an ensolite pad was placed above the backwedge to prevent scapula impingement. The ensolite was cut to match the contour of the backwedge then placed in a pocket that was sewn to the cushion. Velcro was used to keep the ensolite on top of the backwedge.

The position of the rudder pedals and instrument panel mock-ups were verified prior to the tests by use of the templates shown in figure 12. As indicated in table III only one subject contacted the instrument panel, an improvement over previous testing, reference 2. However, it should be noted that no long legged subjects were available for testing.

TABLE III
SUMMARY OF TEST CONDITIONS

F-18 Escape System Update
Physiological Acceptability Demonstration

Test No.	NADC Test No.	Date	Air Temp (°F)	Subject Ejected Weight (lbs)	Acceleration Curve Onset (G/Sec.)	Peak Seat Acceleration (G)	Separation Velocity (Ft/Sec.)	Ejected Rail Height (Ft.)	Notes Remarks (On Next Page)
1	38	5-1-83	75	164	196	15.1	54.9	50	Dummy Test
2	37	5-1-83	73	164	144	12.7	50.8	44	Dummy Test
3	03	4-13-83	55	164	114	10.5	49.2	39	Dummy Test
4	36	5-1-83	70	164	77	7.8	39.8	29	Dummy Test
5	101	6-8-83	70	159	55	6.7	34.0	26	–
6	102	6-8-83	14	212	61	6.6	36.3	25	–
7	103	6-8-83	79	205	52	7.1	36.7	25	Note 1
8	104	6-8-83	79	201	40	4.5	30.1	20	–
9	105	6-10-83	70	161	75	8.8	40.7	33	Note 2
10	107	6-10-83	72	212	91	9.5	42.1	34	Notes 2 & 3
11	106	6-10-83	72	204	73	8.8	41.6	33	Note 2
12	108	6-10-83	74	201	75	9.3	42.0	34	Note 4
13	109	6-14-83	80	161	56	7.4	38.1	30	–
14	112	6-14-83	85	212	147	11.5	42.2	42	–
15	111	6-14-83	85	205	126	11.3	46.2	42	Notes 1, 5 & 6 Not Acceptable
16	110	6-14-83	83	200	114	11.6	47.9	41	Notes 6, 7 & 8
17	114	6-16-83	87	161	170	14.3	53.8		Notes 3, 6 and 8
18	115	6-16-83	90	209	137	13.8	52.9	50	Notes 3, 9, 10 & 11
19	118	6-23-83	85	207	177	13.7	52.6	50	Note 6
20	116	6-16-83	92	200	133	14.0	52.0	51	Notes 6, 7 & 12

REMARKS

1. Petechiae on the subject's chest near the harness strap locations.
2. Redness, minor abrasions or minor contusions on the subject's back near his shoulder blades.
3. Singed hair or powder burns on the back of the subject's legs. (Figure 1)
4. Tenderness near the subject's shoulder blades but no marks.
5. Small blood clot below the right scapula, contusions and abrasions below both scapulas. The pain below the right scapula persisted for over 24 hours. This condition is unacceptable. (Figure 2)
6. Tenderness or bruising on the subject's calves. (Figure 3)
7. Tenderness near the subject's coccyx.
8. Soreness of the neck and upper back the following day.
9. Subject experienced severe chest pain 3-4 hours after the test. EKG, chest x-rays and cardiac enzymes all indicated normal.
10. Headache.
11. Subject's toes contacted the instrument panel mock-up.
12. Subject's toe didn't contact the toe guides or the instrument panel mock-up.

ACKNOWLEDGEMENTS

The author wishes to extend his appreciation to those personnel from the technical services department who participated in this program. In particular, special appreciation is extended to the four volunteer test subjects:

HMC W. Miller
HM1 M. Ammerman
HM2 J. Cisco
HM3 D. McGee

REFERENCES

1. TWD No. LMA-05.08-083 F-18 Escape System Update Physiological Acceptability Demonstration.
2. NADC Report No. 79040-60 Physiological Acceptability Tests of the SJU-5/A Ejection Seat 1 Feb 1979.

Figure 1. Powder Burns on Subject's Calves

Figure 2. Bruises on Subject's Back

Figure 3. Bruises on Subject's Calves

Figure 4. Template Showing Proper Seat Full Down Configuration

Figure 5. Template Showing Proper Seat Full Up Configuration

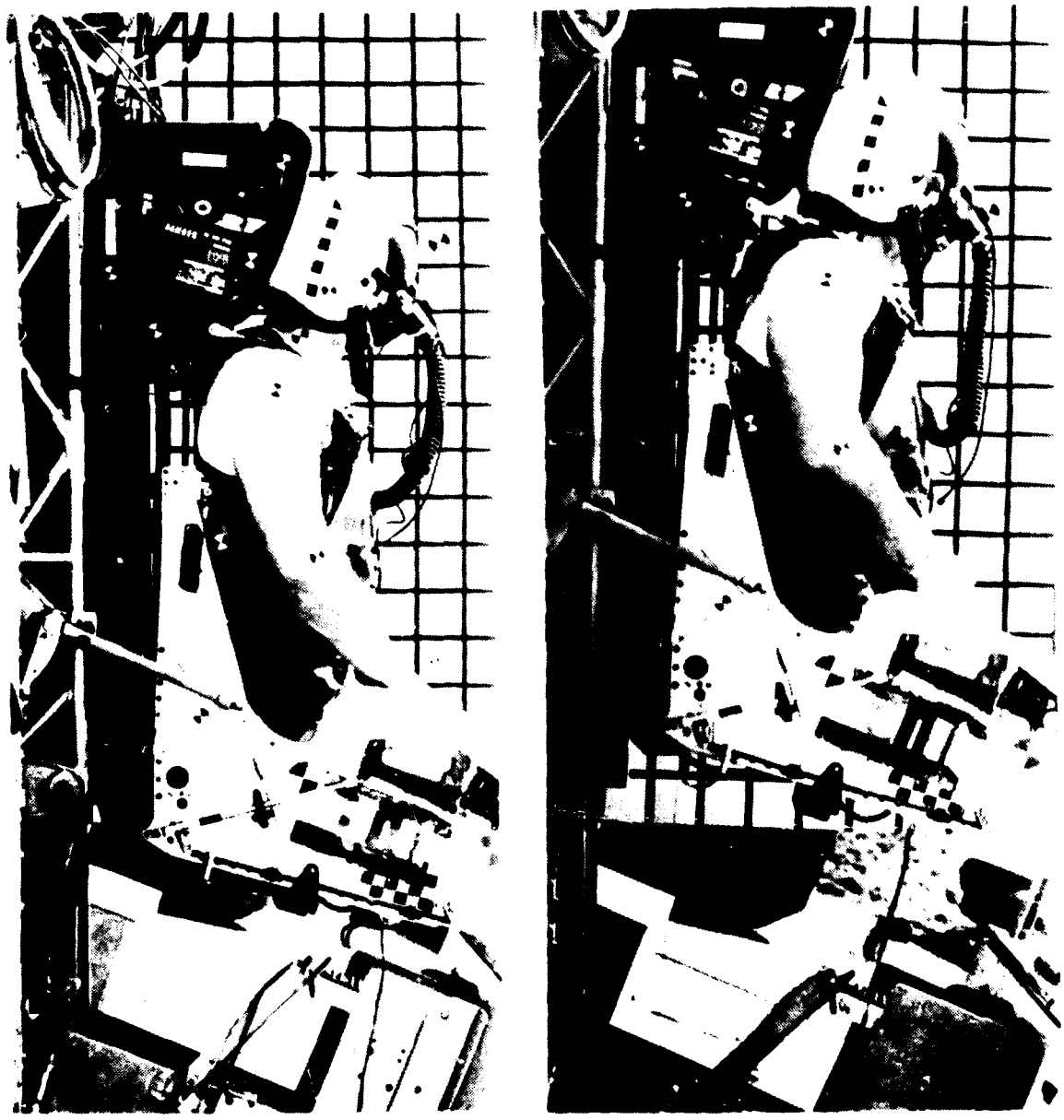
Figure 6. Subject No. 1 at End of Catapult Stroke

Figure 7. Subject No. 2 at End of Catapult Stroke

Figure 8. Subject No. 3 at End of Catapult Stroke

Figure 9. Subject No. 4 at End of Catapult Stroke

Figure 10. Scapula Location for Subject No. 3



Before Ejection

6 In. of Seat Travel

Figure 11. Subject 3 Before and During Test No. 15

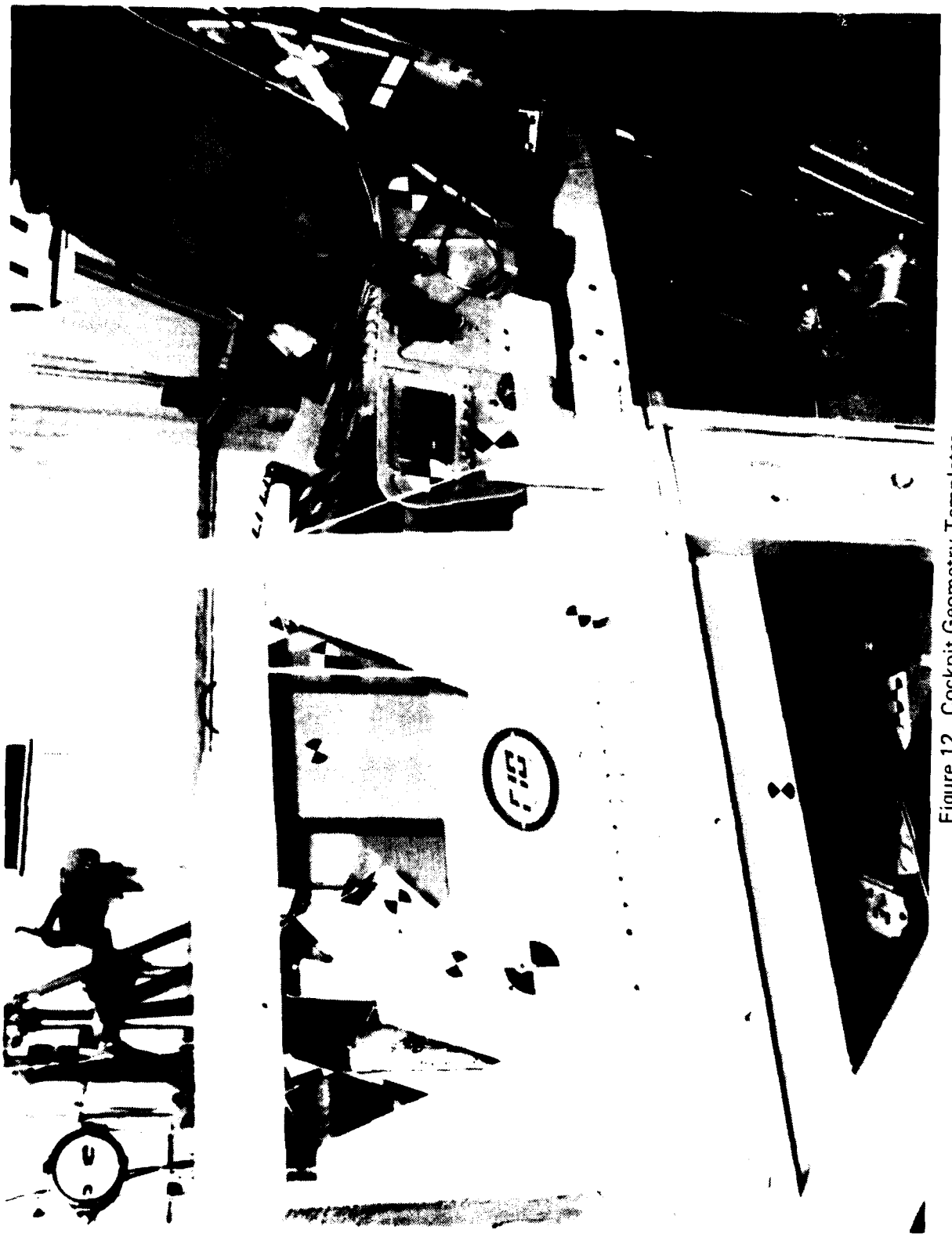


Figure 12. Cockpit Geometry Templates

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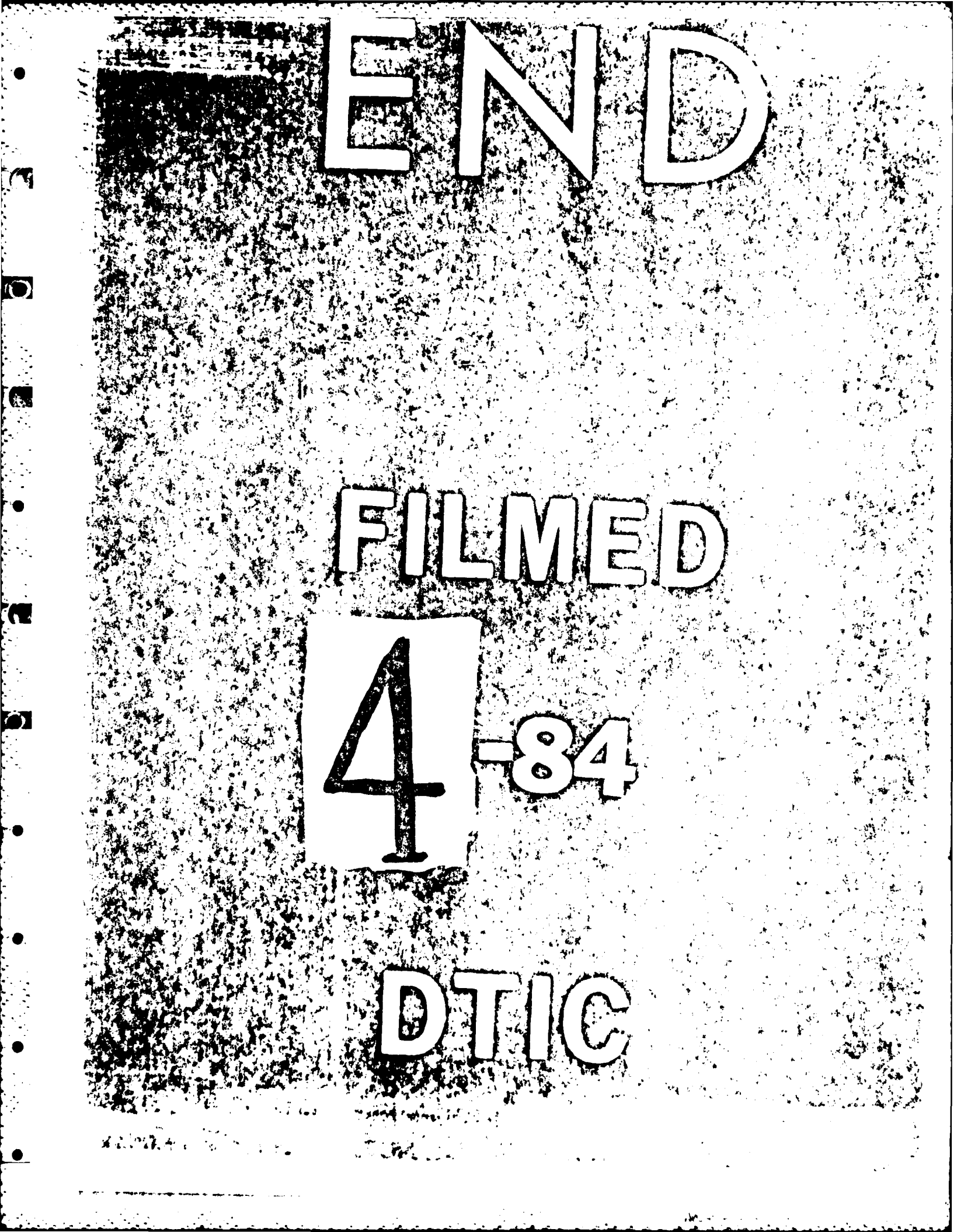
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